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THE INSTITUTE OF PHYSICS

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The Physics of Music

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[Based on a lecture given to the Non-Destructive Testing Group]

INTRODUCTION

To LECTURE with real authority on a scientific topic one should, at some time, have made it the subject of one's own research. The corresponding qualification for a musical topic might be a certain amount of formal training, or a wide professional experience. I have to admit immediately that I cannot satisfy any of these conditions ; my sole qualification is an enthusiastic and abiding interest in this borderline field. My interest has been quickened by the realization—from contact with first-year undergraduates—that sound is becoming a " cinderella " subject in many elementary physics courses. This seems to me to be a great pity ; it may have certain disadvantages as an examination subject, but it does provide great scope for demonstration experiments and offers excellent opportunities for introducing scientific ideas to arts students and also for broadening the minds of future scientists. One of the purposes of this lecture is to try to substantiate the claim that it is possible to convey much of the scientific basis of music without assuming that the audience has any scientific training. I hope that I shall be able to interest the non-scientists ; I hope also that the scientists will not be too bored.

There are no new ideas in my lecture ; it is really a collection of experiments which fascinate me and which I am never tired of demonstrating. In order to give it some kind of continuity, however, I want us to imagine that we have the problem of designing a musical instrument from first principles. Since this is the Non-Destructive Testing Group, we should obtain all our design information from existing instruments merely by listening to them and observing them in use. The lecture will be concerned with some of the experiments that might be performed in order to carry through such a plan.

MUSIC AND NOISE

The first step is to decide what is meant by a musical instrument. Without going into too much detail it can be defined as a device for producing a musical sound that can be varied to permit the playing of tunes. This, of course, immediately raises the question " What is a musical sound ? ", or, more precisely, " How does a musical sound differ from any other kind of sound ? ". It will be assumed that we are all aware that sound is transmitted from place to place in the form of compression waves in the air. In order to examine these waves a cathode-ray oscillograph is used ; it will suffice for our present purpose to regard this as a device for drawing a continuous graph of the pressure variations in the waves against time. The spot of light on the oscillograph screen takes about 1/50th sec. to travel from one side to the other and this will give some idea of the scale of the graph. All sorts of noises and sounds have been recorded and the oscillograph is connected to the tape-recorder so that we can both hear and " see "

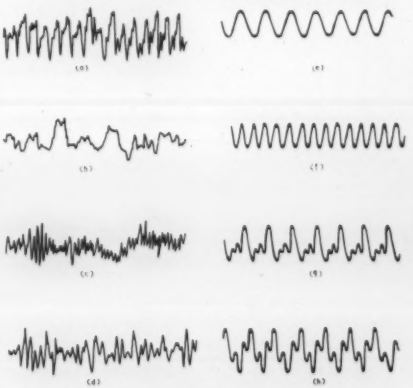

Fig. 1 (a)-(g). *Oscillograph traces of various sounds all with the same writing speed :*
(a) *Fragment of Beethoven symphony,* (b) *Orchestra tuning up,* (c) *Fragment of modern jazz,* (d) *Low-frequency noise,* (e) *Pure tone,* (f) *Pure tone an octave higher than* (e), (g) *Trumpet sounding the same note as* (e), (h) *Calculated trace for a mixture of first and third harmonics.*

the waves at the same time. Although there are differences in the visual patterns it is surprisingly difficult to formulate them. One or two samples are reproduced in Fig. 1. Compare (a), (b) and (c), which are the patterns produced respectively by a fragment of a Beethoven Symphony, an orchestra tuning up and a piece of modern jazz. There could undoubtedly be great arguments about the musical quality. Most people—even if it were not to their taste—would admit the Beethoven as a musical sound ; the jazz might raise more argument ; the tuning sounds, although made by musical instruments, would probably be called noise.

These sounds are all too complicated for the present purpose and much simpler illustrations are needed in order to find the real distinction. Fig. 1(d) is the trace of what physicists call low-frequency noise. It is continuous and sounds like applause ; by no stretch of imagination could any musical quality be assigned to it. Compare this irregular jumble of peaks with Fig. 1(e), the trace corresponding to what physicists would call a pure tone ; it is in fact the note A used by orchestras as a tuning note. Although very uninteresting aesthetically it has undoubted musical quality and its oscillograph record is completely regular. Time prevents further investigation now but further experiments would show that the essential quality of a musical sound from the scientific point of view is regularity. As soon as any degree of repetition occurs in the visual pattern, the sound begins to assume a musical quality.

SOURCES OF MUSICAL SOUNDS

The definition of a musical instrument given above included not only the production of a musical sound but also its variation to produce tunes. A recorded " gliding-tone " can be used to demonstrate that the scientific counterpart of musical pitch is the frequency at which the pattern repeats. (Fig. 1(f) corresponds to a pure tone an octave higher than that of 1(e) and having double the frequency). The problem is thus to produce a regularly repeating pattern of compression waves and —if tunes are to be played—to vary the rate of repetition. Vibration of some kind springs to mind and it is necessary to find objects that can be made to vibrate. It soon becomes apparent that almost anything can be used as a vibrator if it is treated in the right way. " Treating it in the right way " corresponds to learning to play a musical instrument. It is easy to demonstrate some quite unexpected sources of musical sounds.

For example, if a solid brass rod about $\frac{1}{4}''$ in diameter and about three or four feet long is held at precisely the mid-point with one hand and stroked vigorously from the centre to one end with a resigned cloth gripped in the other hand, a very loud and penetrating note is emitted. A rod of different dimensions gives a different note and so it would, at least in theory, be possible to produce a primitive musical instrument by having a large number of rods of different dimensions ; tunes could be played by picking up the rods in the right sequence. This would certainly not be a very practical instrument, but it does illustrate the simplest way of changing pitch to produce tunes, that is to have a different vibrator for each note. The piano, organ and harp, among others, use this principle.

The second unpromising instrument is a length of thin brass plate about 2″ wide and 3′ long, which if merely dropped makes a sound that can only be described as a clatter. If, however, it is held in a certain way and bowed with a cello bow on the edge, it can emit a definite note, and if the plate is bent slightly the pitch can be changed. Again, this is not a practical musical instrument, but it illustrates another of the ways of changing pitch by changing the shape or tension of the vibrator. Many instruments fall into this category—strings, woodwind, and so on.

A modification of this same basic idea is used in the musical saw. You will have undoubtedly heard this " instrument " before and may have thought that some very special kind of saw was used, but in fact any flexible saw will do. The trick consists in knowing how to hold it, and where to bow (see Fig. 2). The saw emits a very loud note, and its pitch can be varied fairly

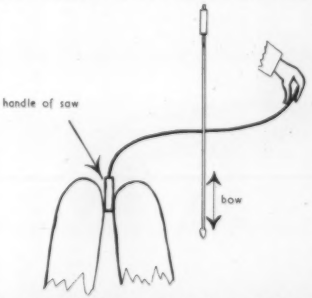

Fig. 2. *Method of holding saw. The handle is clamped between the knees of the seated player, and the blade bent and held by the left hand.*

easily by altering the degree of bending. Although it does tend to get out of control, it is possible with practice to play a recognizable tune. It may be noticed that at some points while playing on the saw there is a sudden jump in the frequency of the note produced. This leads us to the third main group of instruments, those using change of mode of vibration. This is not just a change in frequency but a complete change in the vibration pattern. There is a very famous experiment in physics which illustrates change of mode rather beautifully ; it is the Chladni plate. This is simply a square plate of brass painted white (emulsion paint provides the least damping). If it is bowed and held in certain ways it can be made to produce many different notes. If, at the same time, black sand is scattered on it the sand tends to collect at the places where the vibration is least violent, and outlines the pattern of vibration (Fig. 3) ; the smaller units of pattern produce the higher notes. A full analysis of the vibration of the plate is quite complicated but it illustrates the basic principle of the third main group of instruments—including all the brass—which use a change of mode to vary the note.

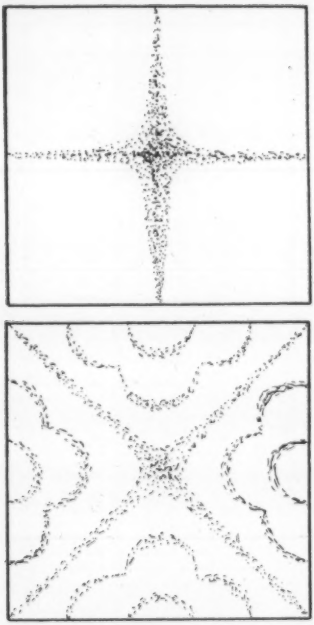

Fig. 3. *Two typical sand figures in the Chladni plate experiment.*

PURE AND INSTRUMENTAL TONE

There are obvious differences in quality between the pure tones used at the beginning, the notes produced by the primitive instruments described in the last section and those produced by real instruments. The source of these differences must now be investigated. Fig. 1(g) shows the trace of a trumpet sounding the same note as that of 1(e). Although the repeat interval is the same, the pattern which repeats is obviously different.

The experiment with the Chladni plate leads to the idea that it may be possible for an instrument to vibrate in more than one mode at once and so give rise to a more complex tone. If, instead of bowing the plate, it is struck with a hammer it is possible to hear many notes at once. As pointed out above the analysis of the vibrations is difficult but it may be greatly simplified if one dimension is made very small ; the plate then becomes, in effect, a stretched string. It is difficult, however, to persuade sand to balance on the string ! Instead use is made of another familiar research trick, that is to study a large-scale model. A suitable large model of a guitar string would be a solid-rubber cord about $\frac{1}{4}''$ in diameter and 20′ long ; its vibrations are large enough and slow enough for easy observation.

If the cord is fixed to a support or held by an assistant at one end and the other end is made to move up and down, a series of modes of vibration can be produced. (This is merely a large-scale version of Melde's experiment.) In the simplest the whole cord vibrates together with maximum amplitude in the middle. The second has a null point in the middle and two maximum loops. The third has two null points and three maxima, and so on. It can easily be verified visually that the ratio of frequencies for these modes is 1 : 2 : 3 etc. If the cord is plucked at some point a definite wave may be seen travelling up and down and it is easy to verify that the frequency of passage is the same as that for the simplest mode of vibration. The precise form varies somewhat according to the point of plucking. Careful study shows that the complex shape is the sum of the first and certain of the other modes in various proportions. Plucking the cord corresponds to hitting the Chladni plate with a hammer and again the idea that the quality is dependent on the various modes or harmonics present emerges. Fig. 1(h) is the calculated pattern for two modes with frequency ratio 1 : 3. It already shows the beginning of a resemblance to the trumpet pattern (1(g)) and if we included more harmonics and varied the relative proportions it would be possible to make the calculated pattern correspond very closely with that obtained in practice.

IS HARMONIC CONTENT ENOUGH TO DETERMINE QUALITY ?

So far in the search for information enough data have emerged to produce, in theory at least, an instrument which will produce vibrations of variable frequency and by mixing these in various combinations, imitations of various real instruments should be possible. Early electronic organs did just this. But few of them could be said to imitate instruments with any degree of fidelity. A tune may be " played " by a pure tone audio signal generator and the effect is rather unpleasant particularly because, unless some special provision is made, the pitch glides continuously between the notes of the tune. This begins to give a clue to further important factors, and further experiments—especially careful listening to actual instruments—suggest that the way in which a note starts and stops may be very important and may possibly be quite different from the way in which it continues. For example, the oboe begins with what can almost be described as a quacking noise, the flute begins with a breathy sound, and so on. Obviously, the way a note starts has a profound influence on the quality. The real reason for these variations in starting is that nearly all musical instruments do not consist of simple vibrators. For example, a bagpipe chanter consists of two components, the reed and the pipe. The reed starts the vibration, it is then taken up by the pipe, but this pipe vibration reacts back on the reed and there may be a kind of argument before they finally agree on a joint vibration. It is this " argument " which gives rise to some of its characteristic quality. It is, of course, necessary in instruments to have these so-called coupled systems. Many vibrators are not powerful enough to give an appreciable sound on their own ; a tuning fork

is a good example of this. On its own one can hardly hear the note, but immediately it is put down on a table or other board one can hear the sound. The vibrations are transferred to the large surface, and so a much larger amount of air can be set in vibration. A tuning fork on a resonating box provides another example. In a violin the body produces a very large part of the sound, as can be shown if a " violin " is constructed with a solid rod connecting the neck and tailpiece with no body at all ; in every other way it is the same as a normal violin, but the sound is very weak.

We might thus expect starting transients in all instruments, but clearly in some they will have a greater effect than in others.

It is interesting to look a little more closely at a coupled system, and a model may be used to demonstrate (Fig. 4).

One part of the system is a weight on a spring which can oscillate vertically ; this corresponds, for example, to the

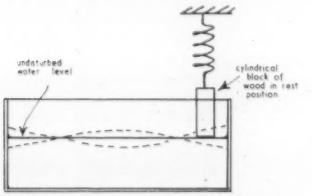

Fig. 4. *Side view of perspex tank showing undisturbed water level. The dotted lines indicate the extremes of movements of the water surface when the steady state is reached.*

reed of a wood-wind instrument. The other part is the water in the tank which can be made to vibrate in an analogous pattern to the way the air in the pipe of a wind instrument vibrates. If the two are now brought together it will be noticed that for some time the oscillation is erratic, and then quite suddenly the two components seem to reach agreement and vibrate together. The effect of this in a real instrument may be demonstrated with recordings. A recording of an oboe playing the normal scale is compared with a second recording precisely the same as the first except that for each note the initial part of the recording has been wiped out. (This is most easily done during re-recording if two tape recorders are available). The so-called starting transient is not heard. Something like the same technique that is used in cinema photography to demonstrate effects in slow motion may also be used by recording with the tape running at a very high speed. If this is done for a flute playing a rapid series of staccato notes, and then it is played back at about 1/3th of the speed, the pitch of course goes down, but the important point is to notice the comparatively long period of " breath " and then the slight gap before the note actually begins. The same thing may be done with a trumpet and piano or other instrument.

PRACTICAL CONSEQUENCES OF TRANSIENTS

The effect when transients are missing may be illustrated in several ways. First with some recordings of pairs of instruments playing together, in which the starting transients have been artificially removed. It becomes more difficult to say which instruments are involved. A similar test with three instruments playing a chord creates even more difficulty. A more amusing demonstration can be given by reversing the tape on the recorder. The starting transient then comes at the end instead of the beginning. This has the unfortunate effect, of course, of making the tune go in the reverse direction as well ; this last effect can be remedied by asking the performer to play the tune backwards in the first place. Then, when the tape is reversed, the tune comes out the right way round, but all the transients are reversed. This has been done with fragments of tunes for the oboe, flute, clarinet, bassoon, violin, but perhaps the most startling effect of all is with the piano ; here the transient is very violent, and, when it is removed or reversed and made to follow instead of lead, the piano sounds like an organ.

CONCLUSIONS

There are many other contributory factors which are outside the scope of the present lecture. One, for example, is the effect of vibrato ; the " slow motion " technique may be used to illustrate how important this is. For example, if a flute recording at the normal speed is compared with one at half speed it is noticed that with the vibrato frequency halved the effect is most unpleasant. Time does not permit this to be pursued any further at the moment. However, as a result of this brief introduction to the physics of musical instruments, it may well be that the next time a Symphony Orchestra is heard some thought may be given to the enormous number of physical experiments that are being performed. Each one of the 70 or so players is producing vibrations of a given frequency, is struggling to maintain his instrument in the right mode of vibration and with the right admixture of other modes, and is anxiously striving to achieve the right starting transient on each occasion when a note is required from him. In other words one might regard a symphony concert as the simultaneous performance of a vast number of experiments in the Physics of Music. This is an interesting thought, but I suggest that it may be just as interesting and useful to sit back and enjoy what might reasonably be called the Music of Physics.

Vol. 11, October, 1960

A Laboratory Apprenticeship Scheme

B. E. NOLTINGK*
Ph.D., F.Inst.P., A.M.I.E.E.
Tube Investments Research Laboratories, Cambridge

A good deal of attention is currently given to the question of training for the unprecedented conditions in industry and research that have been brought about in a short space of time by scientific development. There has been particular concern with the role of universities and colleges of higher technology, and with the students attending them; that is at least a clearly defined field. It is often admitted that such education is only part of the problem, and that our national productivity in science might be greatly increased by the provision of more effective support for the scientists as well as by increasing their number. However, the factors concerned in improving the quantity and quality of this supporting effort are diverse and complex and may have received less than their fair share of attention. Recently there has been evidence of a greater awareness of the training problems on the "lower deck," and a brief account of the system adopted at one laboratory may prove of interest. No doubt similar ideas have been pursued elsewhere, but there does not appear to have been a description of anything worked out in quite such detail.

OBJECTIVE

Hinxton Hall was established some five years ago as the fundamental research laboratory for a large group of companies with very widespread interests. It did not require fundamental research to discover that a major problem was the recruitment of an adequate labour force† to support the work of the scientists who had been enlisted. Partly to help a national need, and partly in enlightened self-interest, it was resolved to train our own. A scheme was devised and implemented, and although it is still too early to judge its outcome fully, the first indications are that it is proving successful.

The sort of man who is required is one who will see to the day-to-day practical running of a laboratory. He will construct and assemble equipment. He will take a large part in experimental observations, these being left entirely to him once they have become routine. He can be told in a sentence to set up the apparatus for this particular material under such-and-such conditions, instead of being given detailed descriptions of the current needed and the cleaning procedure for the critical surface and how to work out what is the maximum safe operating pressure. He will train an occasional junior by practice as well as precept. He may well be a little jealous of the scientist who ventures into his room to untidy his shelves and make doubtful soldered joints in his apparatus!

Many of the qualifications needed are severely practical ones, but there is a tendency for mental ability to grow in importance compared with manual dexterity. This follows partly because more and more elaborate equipment is now available commercially. It is also partly because the pace has quickened so that the technician spends an increasing proportion of his time on techniques that were unknown when he first trained and for which the only preparation can be a broad general grounding.

Within this specification of objective, there is a wide tolerance, for a good laboratory is a flexible structure with a corresponding tolerance allowing the responsibility assumed by any individual to be governed by his capabilities. Often, several good technicians can report to a single scientist, while most places have some unavoidable routine burden which can be allotted to those with less initiative.

RECRUITMENT

Once a year, applications are invited from school-leavers to attend a competitive interview at which that year's intake of three or four apprentices are selected. The local youth employment offices are very co-operative with recommendations: the influence of school-teachers is also most important and some trouble has been taken to cement good relations with them, to explain our function and to suggest what type of individual is most likely to be attracted to a laboratory apprenticeship. Visits by teachers and pupils have both proved rewarding. This policy has brought a steadily increasing return, with the establishment of a definite reputation as employers who are small, selective and sought after. The rising quality of applicants—though perhaps not uninfluenced by general economic history—has been a considerable encouragement. It has allowed, what is nowadays a luxury, the refusal of a candidate who would have been acceptable, but has a rival of even higher standard.

We drain from a wide catchment area: public school, grammar, technical, secondary modern and village college are all represented. Most apprentices start at sixteen years old, some a month or two less, a few at seventeen or eighteen. No paper qualifications are insisted on. Most arrivals have a few O level G.C.E. passes, ranging in fact from one to nine. It would, actually, be very difficult to use a G.C.E. criterion, from considerations of relative phase in the annual cycle, since selections are made and most apprentices

* Now at Central Electricity Research Laboratory, Leatherhead.

† Even the name of these most essential people is not universally agreed. I prefer "technician" to the commoner "assistant," because the latter is so ambiguous. A laboratory assistant may do little but sweep floors, whereas, in the first research establishment I worked at, everybody for several grades below the director, Ph.D.s and all, were officially assistants of one kind or another. Also "apprentice technician" means something, whereas "apprentice assistant" is almost self-contradictory!

have started work before the results are announced; a concession to the importance of G.C.E. is made by small adjustments in the rates of pay. The chief characteristic looked for is an enthusiasm, whether dogged or vivacious, that can be harnessed to the creative work of a laboratory; if that is present, accompanied by an academic competence, we feel that we have good material. No sex discrimination is introduced—beyond what is endemic in our national educational system—and several girls are justifying the confidence that was placed in them. Selection on an individual basis, rather than by any mechanized procedure, seems to bring more naturally a personal concern with subsequent careers, rewarded by a more personal loyalty to the laboratory. No doubt this requires more diligent pursuing in a larger establishment.

The apprenticeship lasts for five years. The first year is a formal probation, at the end of which a back-dated agreement is signed. Three parties are involved, the company, the apprentice and the parents, emphasizing the obligations all round. At the end of his term, the apprentice receives his agreement back, completed; since it indicates the fields in which he has received practical training, it should have a definite value for his future career.

TRAINING

The aim of the whole apprenticeship scheme is to produce useful laboratory workers. In engineering works, it has long been recognized that a sound foundation of training is built upon a variety of experience in many different departments, and most apprentices travel round from department to department for several years. It is perhaps surprising that the same principle has not been so generally accepted for laboratory technicians, and it is essentially on this that the Hinxton apprenticeship is based. The laboratory is well suited for giving a variety of experience, owing to the diversity of its interests, which embrace physics, metallurgy, chemistry and engineering within an establishment that is still small enough to retain a close mutual familiarity of specialists across their different frontiers.

Each apprentice, then, spends about five periods of six months each in different departments, before settling down to a final two-and-a-half year spell in one department. A fair acquaintance is thus gained with the techniques in several different fields—one or more of which is generally in a "service" area, workshops, electronics, glass blowing or photography—and a very thorough training in one field. Full attention is paid to individual preference and ability in deciding the allocation to departments, though there is of necessity a compromise with the needs and capacities in different areas. Probable final destinations are kept in mind as soon as they can be forecast so that the most useful subsidiary techniques can be learnt. A typical apprentice has been in succession to Polymers, Workshop, General Metallurgy, Strength of Materials and Corrosion. He should complete his apprenticeship in Corrosion Section at the same time as he gains his Higher National Certificate in Applied Physics.

A continual discussion rages as to how far apprentices may be used as cheap labour and how far there is an obligation to devote time and effort to training them. But in fact the problem is largely taken care of by an insistence on uprooting and moving on every six months. The regulars in any laboratory are compelled to train new arrivals before any useful work can be gained from them, and even routine tasks are quite profitable experiences when only kept up for a month or two. With the slight excess of senior staff that holds at present, the system is largely self-adjusting: since their mentors are anxious to get rid of work at as high a level as possible, apprentices tend to be tained for and used at work of the maximum responsibility they are capable of. Perhaps, with training done as much by scientists as by senior technicians, there is a danger of too precocious an end-product. It has been interesting to note a change in attitude of the scientist-customer; whereas at first apprentices were accepted as one of the trials to be endured for the sake of the future, there is now almost a scramble to gain as large a share as possible of them.

Each department has compiled a "list of skills" in most of which an apprentice would expect to receive instruction while he is in that department. When he moves on, a copy of this list goes in his file with a tick against those actually learnt—though with no formal examination. A tabulated report is also made by the person to whom he has been responsible. Too much significance must not be attached to these; their main purpose is as a reminder that formal training is expected to be given. In principle, reports also provide information on the kind-heartedness, etc., of the reporters, but a fair body of statistics must be amassed before this can be reliable !

It might be argued that an initial period of whole-time training in an apprentice school would be beneficial. This has been rejected, partly on the grounds that the diversity of ultimate interests would reduce the field of profitable common learning, but more because the small numbers in an annual intake would not justify the services of a whole-time instructor.

All apprentices continue formal schooling under a day-release scheme which allows attendance at the local technical college. National Certificate courses in Applied Physics, now that these have been introduced, are appropriate for the majority, though one or two take Chemistry or Engineering and one or two might take Metallurgy if it was available. These courses appear quite satisfactory for the purpose, though the detailed inter-relation of academic and practical training, often talked about, is in practice rather fanciful at least at the lower levels. Technical College results afford a good way of sorting out the more intelligent-industrious from the less (the excess of diligence required to offset a deficiency in intelligence evidently increases rapidly as the course progresses). The impression is gained that a technical college—as might be expected—tends to be more a machine for squeezing the maximum number of candidates past an examination, than an educational establishment in the wider sense; it behoves those who contrive syllabuses to ensure that the two objectives are no further apart than they need be.

OTHER ACTIVITIES

The apprentices are encouraged to arrange lectures about once a month on matters of general technical

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Senior Personnel Officer, Osram Lamp Division, G.E.C. Estate, East Lane, North Wembley, Middlesex.

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quoting reference
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Glasgow Herald

Price to members, if ordered through the Institute and Society, **6s. 6d.** including postage.

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Chapman & Hall Ltd.

interest, the lecturer normally being a member of the laboratory staff. One or two short internal courses have been given to selected apprentices in more specialized subjects such as metallurgy. Occasional works visits show them how the other half of the world lives.

From all this, a fair sense of community has grown up among the body politic of apprentices, which makes, by its interdepartmental flavour, a not insignificant contribution to improving communications between different groups in the laboratory.

END PRODUCT

As remarked previously, it has proved possible to treat each apprentice undergoing training as a specific individual. It is not, therefore, any embarrassment that there is little uniformity in the end-product. An attractive feature of the apprenticeship scheme is that the door is kept open for the brightest individuals to proceed to sponsored university studies or sandwich courses; they can subsequently return to rather higher levels of the laboratory.

At the other end of the scale, in most departments several people are required for the humbler, less skilled tasks, and there will not be an excessive waste if a few ex-apprentices are allotted here. In between, a wide range of technicians, able to accept a very varied degree of responsibility, is required. It is a greater advantage to have ample time to assess each individual's potentialities rather than be forced to judge in a brief encounter whether he would be suitable for one particular vacancy. We are accordingly deliberately vague in defining post-apprenticeship careers; each recruit, in military parlance, has a potential field-marshal's baton, as well as a potential potato-peeler, in his pocket !

Sometimes there is concern whether we will always be able to absorb the full output of apprentices, but an annual intake of three or four does not seem disproportionate to the turnover from thirty or forty technicians. A further outlet, that may be more desirable in principle than it proves realizable in practice, is to furnish in this way a source of skilled men for the industrial production staff of the future. As processes become more involved, so will it be more necessary for personnel trained in the basic sciences to penetrate to the factory floor. A background of laboratory training and a familiarity with research staff and procedures could provide a valuable scientific leaven in many aspects of industry.

It is as yet too early to give a final verdict, but the first indications are that this apprenticeship scheme will make a real contribution to the widespread need for technicians trained in laboratory skills. It is likely that something along these lines could with profit be more widely adopted.

The Schools Lecturing Scheme of the Liverpool and North Wales Branch

M. G. DAVIES
B.Sc., Ph.D., A.Inst.P.
University of Liverpool

About three years ago, the Institute of Physics Headquarters suggested a scheme to make known among school boys and girls the need for physicists in industry and their scope of activity. The idea was taken up by the Liverpool and North Wales Branch and the present " Schools Lecturing Scheme " is in the course of evolving from it. At the present time, towards the end of its second session, it is of interest to review its success so far and discuss what may be done to improve it.

Initially about fifty concerns (including separate departments of the larger firms) in the neighbourhood were approached to enquire whether they would be prepared to allow one of their staff to visit and lecture to schools on their activities. For a variety of reasons the majority were not able at that time to help; some considered that physics as such was not of sufficient interest to them to justify their taking part; in some cases, the local offices handled commercial business only and had no one competent to talk about development and production in their industries, while others were interested and hoped to enter at a later date. However, the then secretary, Dr. A. Ashmore, enlisted the services of one or more lecturers from twelve firms and in the first session 9 lectures were given. During the current session, 1959-60, 25 lectures have so far been successfully arranged to date and a few others considered but dropped. Eighteen schools have invited lecturers, seven of them making two requests. The schools concerned are by no means confined to the immediate Liverpool area and have included ones in Blackpool and Ruthin. Since about 120 schools were circulated, this represents a relatively small response. Undoubtedly,

apathy is the greatest single factor preventing better use being made of the service, but we have received comments from a number of teachers saying they hoped to invite speakers in the future and the scheme is to be continued.

A meeting was held here in May at which school teachers and lecturers gave their views on what the scheme had achieved and ought to attempt to achieve; as a result partly of this, and partly of general discussions the original aim has shifted somewhat. The present idea is to consolidate a panel of lecturers from among various firms in the neighbourhood who are prepared to visit schools and to talk about the functions of the scientist and technologist in industry, whether his original specialization be in mathematics, physics, chemistry or in some branch of engineering and also more or less irrespectively of his degree of training. The average school boy (or girl) can have only the vaguest idea of the enormous range of activity that is to be found in industry and yet he has to make up his mind whether to make his career there or not. The scheme is an attempt to present to him a picture of some aspects of one or other industry from the standpoint those taking part (rather than, for example, a pure account of a particular process), in order to add to the material he may draw on in making his choice.

Thus the talks are " Career Talks " in the broad sense of the term. They are not intended as a part of a general education as such, though they will so serve. They are not intended simply to fill in gaps in the programme of a school's Scientific Society (though this often provides the best occasion for presenting a lecture). Nor are they intended as recruiting talks. On the other hand, there seems no reason to place narrow limits on the variety of subject matter a lecturer may discuss; any topic is suitable if it illustrates the ways in which the individual goes about the problems of development, production or administration. As regards the audience, there is clearly little to be achieved in talking to junior forms on careers but candidates for either " O " or " A " level G.C.E. can profit from such talks. Again, school populations differ; some comprise the technicians and some the works managers of tomorrow and a number of teachers stressed that talks designed to meet the needs of all audiences within this range could serve a useful purpose.

It is not intended that a lecturer should deliver a set talk on each and every occasion; in his preliminary contact with the school, he should make inquiries so as to ensure that he gives his audience the type of talk they need. Both teachers and lecturers have said how important an initial exchange of information concerning the audience is; a lecturer must know beforehand, what kind of boys (or girls) he has to speak to, their ability, familiarity with technical terms and so on. Time should be allowed for questions; some teachers have mentioned that this can be more interesting than the formal talk.

Teachers emphasized too how much schools appreciated any machinery, films or demonstrations that accompany a lecture. Although the logical extension of this—a visit by senior boys to the firm concerned—is not formally included in the scheme, visits of this kind can be very valuable. Actually, one of our lecturers remarks that such visits would be more frequent but for the lack of action of school authorities. Normally the firm bears the cost, so that no expense is incurred by the school.

Hitherto, schools have simply been presented with a list of the firms that participate in the scheme together with the names of the speakers, from which to make their choice of speaker; they have been given no indication about the content of the lecture. In the reorganized Scheme, speakers are being asked to give a title to their talk, together with a synopsis in 100-200 words of the type of material they are prepared to discuss. The summary might well contain more material than could be covered in one lecture, so that a selection could be made by consultation beforehand between school and lecturer to meet the needs of the boys concerned. It is also hoped to be able to indicate to schools in future what type of audience a lecture is best fitted for, e.g. potential technicians, technologists, or professionals; whether any films, slides, equipment or demonstrations could be brought; whether the work described is likely to be of interest to girls; and whether a visit to the firm could be arranged (to include a lecture and/or inspection) and the numbers that could be accommodated.

The arrangements are made by three sided correspondence and at least a month is required.

Some teachers have mentioned that their science sixth was too small to justify inviting a speaker. The feeling of the meeting was that a reasonable minimum for the expected audience would be about eight, though if the students concerned were especially keen to learn about some industry, a lecturer might be asked to talk to fewer. In any case, a small school might join with some neighbouring school in arranging a lecture.

Fairly recently we heard of the lecture scheme organized by the British Association. This provides lecture services arranged both regionally and nationally and whose aims are much wider and more general than our own. Since the British Association has undertaken not to operate in an area in which any scheme comparable with their own exists it has not included Merseyside. It is too soon to say whether some combination of these schemes will be possible.

Notes and News

Appeal

It is gratifying to report that already many Members have responded to the Appeal for the newly established "Physics Trust Fund". Indeed, the personal letter to Members in the United Kingdom, which was sent by the President and Treasurer on Friday September 30, prompted some to send by return of post their donations and covenants to subscribe over the next seven years. This, and the continuing response is a great encouragement to those responsible for the affairs of the amalgamated Institute and Society. The Treasurer is acknowledging each of these contributions personally and lists of the donors will be included in the *Bulletin* from time to time (but not the individual amounts subscribed).

Any Member who has mislaid his copy of the Appeal or who desires further information about it is invited to write to the Treasurer.

The early reactions from industry to the Appeal have also been encouraging and some generous promises and donations have already been received. The names of the firms subscribing will be published in the *Bulletin* from time to time. Reports on the total amount received and promised will also be given periodically in the coming months.

Qualifications acceptable for membership

Prior to amalgamation, a sub-committee of the Institute's Membership and Education Committee had been making a careful and exhaustive revision of the lists of degrees and diplomas acceptable for membership. The sub-committee's report has now been approved and adopted by the Council of the Institute and Society and its recommendations will come into immediate effect for the professional grades, that is for Fellowship, Associateship and Graduateship of the Institute of Physics. The recommendations are intended to establish greater consistency and to remove what some members had regarded as anomalies.

The principal honours degrees in physics of all United Kingdom universities and such other universities as are specifically recognized will continue to carry full exemption from the Graduateship examination. Similar recognition will be accorded to Diplomas in Technology specially accepted. General honours degrees will be accepted only if certain criteria are satisfied and each degree of this kind is being considered separately. Among those so far approved for this purpose is the London General degree under the *new* regulations with first and second class honours and with physics and mathematics as the subjects of the Part II examination: the London General degree under the old regulations is not accepted. The full list of accepted degrees is included in a booklet giving the regulations and syllabuses of the Graduateship examination, copies of which are now available.

Council has also agreed that an academic qualification shall normally be required of candidates for the grade of Fellow of the Physical Society. The list of degrees acceptable for this purpose includes many of the degrees that would not comply with the regulations for the professional grades. This list will be published shortly in a new edition of the membership regulations for all grades.

Application and transfer fees

Council has interpreted By-law (f) to mean that those who were Associates or Graduates of the Institute on the date of adoption of the new By-laws (June 22, 1960), as well as those who were Fellows of the Physical Society, shall not be required to pay any application or transfer fees on election to a higher grade.

Annual Exhibition

The Exhibition previously known as "The Physical Society's Exhibition of Scientific Instruments and Apparatus" will now be called "The Annual Exhibition of The Institute of Physics and The Physical Society". It is to be held in the Royal Horticultural Society's Halls from Monday, January 16 (Members and Press only on that morning) until Friday, January 20. A member's pass, giving admission throughout the exhibition, will be sent to each member with the November *Bulletin*, together with a request form for additional tickets and an order form for the exhibition handbook at the special rate for members.

Dates to note

The annual dinner of the Institute and Society will be held at the Park Lane Hotel, London, on Tuesday, May 2, 1961. On the same day a meeting will be held at which Sir John Cockcroft will deliver his Presidential Address.

Council has decided to hold a Convention in 1962. This will be broadly along the same lines as the Institute Conventions held at Buxton, Bournemouth and Oxford, with a program designed to be attractive to both members and their ladies. The 1962 Convention will take place in Harrogate on May 23-27.

Symposium on "Electrical Contacts"

The Institute and Society is arranging a Symposium on "Electrical Contacts" in collaboration with The Institution of Electrical Engineers which will take place in Brunel College of Technology, London, on April 3-7, 1961.

The Symposium is intended to cover recent advances in the study of the phenomena occurring at mating surfaces carrying currents used in light electrical engineering. It will include electrical erosion and material transfer, mechanical wear, and the influence of surface films and contamination and will deal with make-and-break contacts, sliding contacts, semi-permanent contacts and connexions, between metallic and non-metallic materials. In view of the nature of current developments, it is considered that major interest will be focused on aspects relating to contact resistance. Further details will be available in the New Year.

The Symposium is intended mainly for persons concerned with the design and improvement of contacts.

There will be a small informal exhibition which will be open during the Symposium to those attending the meetings. Abstracts (but not preprints) will be circulated before the Symposium, the proceedings of which will not be published in full.

Symposium on the Dounreay Fast Reactor

The British Nuclear Energy Conference of which the Institute and Society is a constituent body, is arranging a Symposium on the Dounreay Fast Reactor to be held on Wednesday, December 7, 1960, at the Institution of Mechanical Engineers, Birdcage Walk, London, S.W.1.

Further details can be obtained on application to The Secretary, The Institution of Mechanical Engineers, 1 Birdcage Walk, S.W.1.

Conference on Optical Instruments and Techniques

A Conference on Optical Instruments and Techniques is being arranged by the British National Committee for Physics under the auspices of the International Commission for Optics. It will be held in London on July 10-14, 1961. Enquiries should be addressed to Mr. K. J. Habell, F.Inst.P., National Physical Laboratory, Teddington, Middlesex, England.

Thermoelectricity Conference, Durham 1961

A Conference is being arranged to take place in Durham between July 10 and 12, 1961. Accommodation will be provided in Grey College; meetings will be held in the Applebey Lecture Theatre and in the Applied Physics Department.

It is intended that the topics for discussion include thermoelectric refrigeration and generation, and the following headings are intended to indicate the main fields of interest:—

> Basic properties of thermoelectric materials, solid and liquid; methods of determining electrical conductivity, thermal conductivity, and thermoelectric power; properties of materials, problems and techniques associated with device developments; thermoelectric devices and their applications.

Offers to contribute should be made as soon as possible to Professor D. A. Wright, F.Inst.P., Department of Applied Physics, University of Durham, Science Laboratories, South Road, Durham.

Congress on Cybernetics

The Third International Congress on Cybernetics will be organized by The International Association for Cybernetics from September 11 to 15, 1961, and will be held at Namur.

Those wishing to attend are requested to advise the Secretariat of the Association, 13 rue Basse Marcelle, Namur, Belgium.

Russian-English technical dictionaries

The New York University Committee for Russian-English Technical Dictionaries has published a 20-page pamphlet, *Russian-English Scientific and Technical Dictionaries: A Survey*, which was prepared for the National Science Foundation. Copies may be obtained from Professor A. F. Hubbell, Gallatin House, New York University, New York 3, N.Y., U.S.A., at 40 cents (U.S. stamps or Unesco coupons) each.

Reviews of Books

THE CORRESPONDENCE OF ISAAC NEWTON—VOLUME II

Edited by H. W. Turnbull

London : Cambridge University Press. Pp. xiii + 552. Price 147s.

This, the second volume of the Newton correspondence, fully maintains the high standard set by Volume I, and to some extent possesses even greater interest and importance. Here is Newton, at the height of his powers, giving to the world, after a period of intense intellectual effort, the *Principia* for which he was to become universally renowned. In fact, due to yet another unhappy clash with Hooke, the third part of the great work was temporarily withheld, but eventually Newton agreed to publish. In all this, these letters reveal the complexity of the situation : the cautious but appreciative attitude of the Royal Society, their financial difficulties in supporting the issue of so elaborate a treatise (a recent volume on fishes having sadly depleted the available funds), and finally the readiness of Halley to accept responsibility for the cost. How familiar all this sounds—the frustration encountered on the way to achieving something monumental. In the end, all was well. On June 30, 1686, Samuel Pepys (President) was desired to license the book, which he did on July 5, and it was published the following year. Incidentally, there seems to be a minor slip in the printed transcript of letter No. 290 (Newton to Halley, of July 14, 1686), in which the parallelogram of forces is illustrated. Newton uses ABDC, clockwise, beginning at the south-west corner, whereas the printed version shows ABCD. (The figures in question belong to pp. 13 and 14 of the *Principia*, as the Editor notes).

This was the age of the birth of the full science of terrestrial and celestial mechanics, and it is not surprising that Newton encountered much vexatious correspondence in the course of it. He was oddly secretive, and earlier on, up to the date of Oldenburg's death in 1677, was accustomed to use him as an intermediary in the exchange of letters with contemporaries. It is hard to see exactly what was gained by this practice, but many of the letters in this collection bring out Newton's reluctance to deal with commentators directly. Even allowing for the condition of communications as they were at the time, Newton's "post" does not seem to have been excessive. He evidently tended to discourage correspondence of a controversial nature, though he took infinite pains to satisfy questioners who approached him gracefully. He wished to be left alone with his thoughts. Clearly, he had that tendency of genius to leave problems on one side for a long time, to return to them when the spirit moved him, or perhaps in the end to abandon them altogether, if subsequently deeper insight had, in his estimation, reduced their value.

The binomial theorem appears for the first time in letter No. 165 (Newton to Oldenburg, June 13, 1676). He had discovered it in 1664 or early in 1665, and some three years later J. Gregory found it independently. In fact, Oldenburg wrote to Leibniz, who was in Paris at the time (No. 169, of July 26, 1676), enclosing a copy of No. 165.

All this correspondence seems to have started with a letter from Leibniz, requesting a proof of some infinite series. In the course of his reply, Newton throws out a hint of his method of fluxions (the differential calculus), but stops before coming to a clear conclusion. History was to show that this was a grave pity, for it provided the background for the long and fruitless argument about whether Newton or Leibniz could be considered the originator of the calculus. This of course did not come to a head until many years later (in 1712), when, unfortunately from this point of view, Newton was President of the Royal Society. In general, the record of events seems to show that outstanding personalities are not immune from very human failings, especially perhaps when things of the mind come into dispute.

Meanwhile, Newton's ever-widening distinction did not prevent him (pre-occupied as he was with his researches) from being a very effective participant in Cambridge University affairs. In February 1686-7, he wrote a draft dealing with the attempt of the Crown (James II) to over-ride the statutes of the University. The Vice-Chancellor at the time was the Master of Magdalene, who with eight other members of the Senate (Newton among them) were summoned to appear before the Ecclesiastical Commissioners in London. The notorious Judge Jeffries—then Lord Chancellor—presided, and treated the learned delegation with his customary roughness. Eventually, the Master of Magdalene, having been deposed, was restored, and matters were regularized at Sidney Sussex College, wherein James II had interfered with the Fellows' privileges. Newton remarked that " An honest Courage in these matters will secure all, having Law on our sides".

To end on a personal note, Newton seems to have suffered from short-sight. As far as is known, he never took any action to correct this visual defect, which he could so easily have done. How skilled he was in the grinding and polishing of lenses, both spherical and non-spherical, is a matter of common knowledge.

Once again, Professor Turnbull and his associates have earned the gratitude of scholars everywhere.

F. I. G. Rawlins.

THEORY OF WING SECTIONS

By Ira H. Abbott and Albert E. Von Doenhoff

New York : Dover Publications Inc. Pp. x + 693. Price $2.95.

The prime reason for the appearance in the Dover series of this eleven-year old book lies in the compilation of data it contains on the geometry and subsonic aerodynamic characteristics of NACA wing sections—sections which form the basis of many present day designs. As such it is to be welcomed, the authors being the first to point out in a new preface that much of the supporting material is now out of date—a defect which they could not attempt to remedy without completely rewriting it.

L. Howarth.

COSMOLOGY—2nd EDITION — CAMBRIDGE MONOGRAPHS ON PHYSICS

By H. Bondi

London : Cambridge University Press. Pp. 182. Price 30s.

This monograph is a healthy cure for the physicist who has decided through unfortunate second-hand acquaintance that cosmology is romantic nonsense. The work is the second edition of the survey by which Professor Bondi ten years ago made a neat and very shrewd map of the distressingly scattered possibilities which faced questioners about the red displacements of spectral lines from distant galaxies.

Bondi generalizes the problem into " What is the largest set of objects to which we can apply laws of physics ? " ; he has always been a genius for relating the complex to the simple, and he characteristically begins from " Why is the sky so nearly dark apart from neighbouring stars ? "

His new edition redistributes emphasis according to the revision of scales which has followed recognition that there are two moduli, not one, connecting luminosity with period of pulsating stars, employing more than one zero point and implying time and distance adjustments.

The great merit of Bondi is to make clear what alternatives really underlie the conventional and very ambiguous term " expanding universe." For instance, " steady state " concepts are not necessarily answering the same queries that were raised by the Relativities of Einstein or of Milne. To-day it is often hoped that radio astronomy will provide estimates of concentrations of distant galaxies for deciding whether matter is continuously coming into being and not a fixed quantity : careful reading of Bondi will show the relation of this to asking whether a stationary universe could simulate " expansion " by an apparent ageing of radiation according to choice of time-scale. There is in this book perhaps the nearest approach yet made to the barrier which blocks all cosmology—the uncertainty as to what can make a time-scale on which " beginning of the universe " might have some meaning.

MARTIN JOHNSON.

THE ROYAL SOCIETY : ITS ORIGINS AND FOUNDERS

Edited by Sir Harold Hartley

London : The Royal Society. Pp. 275. Price 35s.

Wednesday, November 28, 1660, was a great day in the history of the world, the actual birthday of the Royal Society. Incidentally, its meetings continued for many years to take place on that day of the week, until it was changed to Thursdays (because of certain duties which Sir Isaac Newton had to perform at the Mint), as it is now. We must begin by saluting the memory of the twelve founder fellows—Brouncker, Boyle, Bruce, Moray, Neile, Wilkins, Goddard, Petty, Ball, Rooke, Wren, Hill, and noting the grant of two charters. By the first was constituted The Royal Society (July 15, 1662), and by the second The Royal Society of London for improving Natural Knowledge (April 22, 1663).

The stately volume before us—the work of Sir Harold Hartley and a team of distinguished contributors— is exactly described by its title. It is a study of the circumstances, personalities and events leading up to the formation of the Society, rather than a history of the Society itself. In this lies its special value, and gives it a unique place in recording the germination of ideas. More than ever, it reveals how learning and the enrichment of human life depend essentially upon people, and not upon conscious planning. To use a mathematical metaphor, the book is an investigation of the curve (of progress) in the neighbourhood of the origin : it is less concerned with tracing its later locus. With this in view, it is natural and proper that the reader should be presented with an abundance of detail, as if the writers were plotting their points closely together, that nothing be lost. It is a labour of love, by scholars for scholars.

To appreciate, however dimly, what it must have been like to live in the middle of the seventeenth century, it must be borne in mind that the Renaissance, in its first tidal wave, swept in a new era of veneration for classical writing and classical art, but in its full flood a rejection of the philosophy of Aristotle, so far as natural law was concerned, and the substitution of judgement by experiment. Well and truly chosen were the words of the Society's motto, *Nullius in Verba*. Some three hundred years after the event, it is difficult to realize what a revolution this was. As we shall see later on, Robert Hooke—himself a genius of the first order—seems to have been hard pressed at times to provide an experiment of crucial importance for each meeting of the Society. So, the old authority was left behind, and the Fellows were duly afloat upon the rough sea of discovery. Politically, socially, economically, it was a hazardous business : one admires their courage and the force of their convictions. At the same time, their outlook was very practical ; everything was to be tested, not only to learn the truth, but to apply it to the betterment of man's estate. This strong element of materialism needs no emphasis ; it was assuredly present at the outset, if later on it was to become tempered by the introduction of more theoretical and speculative tendencies. As already indicated, we are indeed at the point O of the graph.

Fortunately for the young Society, its promoters were (for the most part) men of imagination rather than mere blind disciples of the new learning. Some forty years previously, Francis Bacon (1561-1626) had published his inductive method for studying Nature. This had come perilously near to being little more than a fact-finding administrative machine, patently incapable by itself of initiating research. But what mattered was Bacon's conception of a " Soloman's House " for scientific learning, an idea on the grand scale, which must have influenced thoughtful people towards what was to become in fact The Royal Society. Quite likely too that men of purpose were casting their eyes over Europe, and did not overlook the foundation of the Accademia dei

Lincei in Rome—with Galileo as a member—in the very early 1600's (reorganized in 1609), and the proliferation of various bodies in France for the study of natural knowledge. All this points clearly to a consensus of opinion that the time had come for England to make a start. Oxford and Cambridge were not without witness in these formative years. Yet one gains the impression that the Universities' part was not as great as it might have been, and that the heart and soul of the new movement were to be found in London. Later on, as is well appreciated, academic interest increased, albeit at first it was rather lukewarm.

At this point, it seems fitting to call to recollection the royal founder and patron Charles II, whose portrait by Lely looks down from behind the President's chair to-day. Towards the end of 1663 he gave the Society the mace, which must be in position before business can begin. Twice he proposed to pay the newly-incorporated assembly a visit, but his intention failed to materialize. The King apparently never concerned himself with the financial difficulties which inevitably occurred, and which were probably at least a contributory cause of the ease with which it was possible for men of means to become Fellows in these early years. But this is a matter of development more than of origins. Basically, the royal patronage proved to be of value, because it shielded the Society from attack from unsympathetic quarters. Distinguished as it was, the tendency for the early flame of zeal to flicker was not altogether absent : events were to show that it took masters of the calibre of Newton and Sloane to transform what Robert Boyle may have had in mind as the " Invisible College " into a living reality.

Among the twenty-two biographies, many of them accompanied by portraits, there are of course several which physicists will read with particular pleasure. Wren, who demonstrated more clearly than anybody else how science and art can be combined ; Hooke (curator, and responsible for demonstrations), experimentalist *par excellence*, and initiator of hygrometry and much of microscopy ; Croone, who discovered the existence of the point of maximum density of water ; and several others in this galaxy of talent. To study their lives is to catch a glimpse of what qualities go to the making of a natural philosopher. But odd as it may seem, outstanding ability like that was barely enough: there had to be men of the world like Oldenburg (a little cantankerous perhaps, but by no means devoid of good points), and scholars like Petty, who adorned all they touched. And so the great story unfolds, and The Royal Society—as a whole—begins to emerge.

One last point, not specifically mentioned in these pages, but perhaps significant. A few members of the circle were eminent clerics, heirs of the Elizabethan Settlement, and probably not untouched by the example of the Caroline Divines. With the British genius for adaptation, the new learning was somehow woven into the fabric of the Establishment, and that without undue distress, as if to illustrate in this particular context the time-honoured precept " And the Truth shall make you free."

F. I. G. Rawlins.

INTRODUCTION TO STATISTICAL THERMODYNAMICS

By Terrell L. Hill

London and Massachusetts : Addison-Wesley Publishing Co. Inc. Pp. xiv + 508. Price 74s.

This book is designed as a text for courses offered in chemistry or physics departments at the advanced undergraduate level. Although introductory it provides a quite extensive coverage of topics of current interest in equilibrium statistical mechanics.

The book is divided into four parts. Part I (Chapters 1 and 2) is concerned with the principles or postulates of statistical mechanics. The treatment is based on elementary quantum—mechanical ideas such as energy levels, states and eigenfunctions, degeneracy, etc.

Part II (Chapters 3 to 13) contains applications of the principles developed in Part I to systems of independent molecules (e.g. an ideal gas) or of other independent sub-systems.

The more complicated but also more interesting problems which arise when molecules can no longer be treated as independent of each other (because of intermolecular forces) provide the subject matter of Part III (Chapters 14 to 21).

Most of the applications in Parts II and III have to do with the classical (High-temperature) limit of quantum statistics. Part IV (Chapter 22) is concerned with problems for which the classical limit is not valid (e.g. helium gas at low temperatures).

Throughout the text each topic is approached with the idea of giving an introduction rather than a complete discussion. Usually this results in the outlining of a somewhat approximate first order theory, the most recent details and refinements being intentionally omitted with a view to keeping the discussion at the level for which it was intended.

The problems given at the end of each chapter vary widely in difficulty, ranging from simple numerical exercises to small scale research problems. The first problems listed in each chapter are referred to, in passing, in the text with the object of getting the student to verify the details.

In all, this should prove a useful textbook for the undergraduate and the postgraduate who require a broad rather than advanced introduction to the subject.

R. G. Siddall.

MOLECULAR STRUCTURE

By J. C. D. Brand and J. C. Speakman

London: Edward Arnold (Publishers) Ltd. Pp. viii + 300. Price 30s.

The steady spread of physical techniques into chemical laboratories, so that, for example, nuclear magnetic resonance has graduated inside fifteen years from a slightly recondite branch of physical research to a routine technique for (sufficiently wealthy) organic chemists, raises special problems of interpretation in view of the mathematical and physical innocence of most chemists in this country. The authors of this book have attempted to explain, with a minimum

assumption of previous knowledge, these physical methods which give us information about the electronic ground states of molecules. Some important ideas which cannot be dodged are discussed in a chapter on wave mechanics, confined essentially to one-dimensional problems, and an appendix on the elements of group theory. The attempt is surprisingly successful. The groundwork is quite enough to make plausible the rather large number of necessary results of physical theory whose proofs are just outside the mathematical interest of the expected reader.

The exclusion of electronic spectra makes a neat but rather artificial boundary for the book. Within this limit a great range of material is clearly and concisely presented. The reader is expected to work, and there is a good range of references for further reading. Most honours students of physical chemistry will, I fear, find it heavy going, but physicists working in or near molecular physics will find it instructive even though the mathematical content is hardly enough for their purposes Physicists tend not to know how accurate physical methods become in the hands of chemists; this book is instructive in that sense also.

The book is well produced and I have found only a few unimportant misprints. The price is very reasonable.

G. Wyllie.

PRINCIPLES OF SEMI-CONDUCTOR DEVICE OPERATION

By A. K. Jonscher

London : G. Bell & Sons Ltd. Pp. viii + 168. Price 30s.

In spite of its clumsy and forbidding title this is a good book. It is concerned primarily with the subject of injection, decay and transport of excess carriers in semiconductors. The first three chapters deal with the basic physical principles governing the behaviour of excess carriers in homogeneous media. The remainder is concerned mainly with the application of these principles to diodes and transistors. There is a final brief chapter on non-homogeneous media. The treatment generally is sound and clear, and within its limited scope the book is a useful addition to the literature of semiconductor devices.

M. R. Gavin.

HIGH TEMPERATURE TECHNOLOGY

London : McGraw-Hill House. Pp. 348. Price 116s. 6d.

The Symposium on " High Temperature : A Tool for the Future ", held in Berkeley, California, in June, 1956, was attended by nearly 600 people. The Stanford Research Institute organized a second Symposium in October, 1959, and this volume consists of the papers presented at this second Symposium on High Temperature Technology, together with discussion in the form of question and answer. The papers cover firstly methods of producing the very high temperatures concerned, particularly solar furnaces, arc image furnaces, and direct arc heating. Then they cover materials for high temperatures very thoroughly, both with American papers, and with a review of English work by Professor White. These include, of course, refractories in general, oxides, graphite, carbide, nitride, and even sulphide refractories, intermetallics, and cermets.

The third main group of papers is concerned with methods of controlling and measuring the high temperatures concerned, and the final group with the chemical reactions and vaporization, measurement of vapour pressure and so on, which can be studied under these conditions. Perhaps the most startling method of producing high temperatures was that, described in the first paper, of carrying out a 1·7 kiloton nuclear explosion 900 ft. underground. Very high temperatures indeed were produced in a large cavity, but the conclusion was reached that as a method of producing chemical products, the process would be entirely uneconomic. Such a process can produce temperatures up to a million degrees, and pressures up to a million atmospheres, but it is decided that these are only of interest to pure science and not to applied science.

The book contains a great deal of useful material for anyone working in this field but it is a field in which progress is so rapid that much of the material is more in the form of laboratory notes, than of textbook data.

M. W. Thring.

RADAR METEOROLOGY

By Louis J. Battan

London : Cambridge University Press. Pp. ix + 161. Price 45s.

The effects of weather on radar operation became apparent very early in World War II when phenomena analagous to optical mirage, and diffuse " echoes " moving with the wind began to be a nuisance on defence radars. With the rapid increase in radiated power and the use of higher frequencies the broad features of radar meteorology were soon clarified, and at the end of the war the open publication of photographs of radar screens showing precipitation patterns, and in particular a P.P.I. display of a tropical hurricane, brought the possibilities of the new methods home to meteorologists.

Dr. Battan began his career as a wartime radar officer in the United States Air Force, and has since taught meteorology in the Universities of Chicago and Arizona. He has an impressive personal experience of research in radar meteorology. His book is a reasonably complete history of the use of radar techniques in meteorology up to about 1958 ; it is the only existing book of its kind. The first three chapters, on " Principles of radar ", " Some properties of electromagnetic waves ", and " Propagation of electromagnetic waves " form a brief introduction to the technique. They are useful in explaining some commonly used methods and jargon, but the attempt, in Chapter II, to go back to the foundations of electromagnetic theory seems misplaced—inadequate or worse for those who need such instruction, unnecessary or even positively distressing to those who do not. The following sections—an outline (more would be of prohibitive length) of the theory of scattering by water, ice, and mixed particles, spherical and non-spherical, and of attenuation by atmospheric gases—are much more satisfactory, keeping a nicely judged balance between the general principles involved and the detail

specific to scattering in clouds. The remainder of the book, two-thirds of its content, is a description of meteorological investigations in which radar has figured. It is hard to avoid a feeling of disappointment on reading it. The early precipitation pictures were so spectacular that they aroused great expectations; the applications to weather forecasting and to the areal estimation of precipitation amounts, as set out by Dr. Battan, fall far below these expectations. The applications to the study of cloud physics are more impressive, but are mainly in the realm of macrophysics, and some, at least, of the results of radar observation could equally well have emerged from careful visual study of clouds and precipitation patterns. There are indications that the next phase of radar-meteorology may be an increasing application of more subtle methods to the study of cloud microphysics. Dr. Battan mentions the possibilities of polarized radiation and continuous-wave Doppler techniques, but the first publication of a meteorological application of coherent pulsed Doppler equipment came too late for inclusion in his text.

With the reservations that the explanation of the fundamentals of electromagnetism should have been sounder, or omitted altogether, and that the date of completion of the manuscript should have been explicit, the book can be said to meet the high claim made on the dust-cover—that it is "a complete guide to the use of radar for studying and forecasting weather". It is beautifully produced, though one feels that a less expensive format would be preferable, if the saving were passed on to the reader. One doesn't want a book of this nature to last for ever. It is carefully written in clear and concise English, and seems singularly free from printers' and proof readers' error.

G. D. Robinson.

PRINCIPLES OF ANALOG COMPUTATION

By G. W. Smith and R. C. Wood

London: McGraw-Hill Publishing Co. Ltd. Pp. viii + 234. Price 58s.

The analogue computer is now well established as an indispensable tool in many laboratories, and computers constructed of standard units are now available commercially. The user of such an instrument needs to have a general understanding of the construction of the standard components such as diodes, potentiometers, and amplifiers so as to be able to use them intelligently and with due regard to their limitations; he does not, however, require to know the finer details of design. On the other hand, he must have a wide knowledge of the many ingenious interconnections of these units which have been devised to perform various mathematical operations. The book under review gives just this information. The description of the basic units occupies only about one-tenth of the book, but contains all the information which the user needs. The remainder of the text deals with programming, the simulation of linear systems, the use of diodes and relays, the use of high-gain amplifiers for the computation of implicit functions, and the generation of arbitrary functions. The exposition is clear, and the reader will find the problems at the end of each chapter a great help in acquiring a grasp of the subject. The book can be recommended to all who are likely to have occasion to use computers.

T. B. Rymer.

THE FAITH OF A PHYSICIST

By H. E. Huntley

London: Geoffrey Bles Ltd. Pp. 159. Price 16s.

The thesis of this book is that a scientist, by studying the truths of natural science, learns so much about the nature of the Creator that he also learns to recognize the style of the Creator's work in the same way as an art critic learns to recognize the style of artists. Further than this, if the scientist is sensitive the style influences the student, helping him to form the right kinds of hypothesis and to reject the wrong kinds of theory; even helping him to interpret the Creator to his fellow-men not lucky enough to be scientists.

A scientific humanist reader might find the book annoying because the author never doubts or thinks it reasonable to doubt, that there is a Creator and that the universe bears the stamp of His design; in particular he thinks that human reason is so shaped by our Creator that whatever reasonable questions we ask, we can confidently expect to discover a reasonable answer. This last expectation is shared by humanists because their faith in human reason is like Dr. Huntley's faith in the Creator; both kinds of faith enable the holder to make decisions which are unjustifiable on statistical grounds; and this is the quality which makes us so superior to computing machines.

The author's analysis of aesthetic appreciation and its relation to personality is helpful, but not complete. The book can be recommended to any Christian who sometimes wonders why he is studying science, or wonders why other people do so. One would like to think that it would open the eyes of a pagan scientist to the Divine nature of his studies, but I hardly think it would do as much as that.

Ernest van Someren.

HOW PHOTOGRAPHY WORKS

By H. J. Walls

London: Focal Press Ltd. Pp. 352. Price 42s.

This is a "popular" book written for the general reader who wishes to know something about the science underlying photography. Unusually in a book of this nature, references are given at the end of each chapter to original papers, and to other books, to assist further reading.

The author, Dr. Walls has specialized in physical chemistry and is now Director of the Forensic Science Laboratory in Newcastle. In this book he has given a very lucid and readable account about the optics, chemistry, physiology and psychology upon which modern photography is based. Difficult points are generally aptly explained by homely analogies, although some analogies are rather involved. The description of the history and development of the subject, especially that of colour photography helps to give interest and clarity to the present state of the science.

The subject matter is divided into fourteen chapters. The formation of the image by a lens is described non-mathematically. Aberrations, lens design and blooming are discussed. Much fundamental chemistry, including hydrogen-ion concentration, is explained and it is shown how this is applied to the processing of film and print. The action of light on matter and a general idea of the quantum theory is included. The chapters on colour photography and on looking at the photograph are particularly good, but what a pity that the diagrams illustrating colour are not in colour. There is an adequate glossary and index.

The title of the book is not a happy one, and some of the expressions used are strange for as scientific a book as this is. For example, it is stated that " Photography was born with this purpose. Three men were chiefly responsible for its delivery from the womb of science." " It has got into the hands of the backroom boys." " They are part of Things as They are."

There are many clear and well explained diagrams and graphs. All the graphs should have their axes labelled. It is stated that nodes in stationary waves are points of maximum amplitude. There is a typographical error on page 243.

Apart from these minor points of criticism, the book is well written and can be strongly recommended to any amateur photographer wishing to know more about the science of photography.

T. H. Tyler.

MODERN PHYSICS

By H. A. Wilson

Glasgow: Blackie & Son Ltd. Pp. xv+473. Price 40s.

This book has been little improved since the second edition. The distribution of emphasis still largely reflects the distribution of Professor Wilson's interests in 1928. Material recently added is mostly better described in other books, and in several places there has been no trouble taken to revise statements in earlier chapters to agree with the new material. More space is still given to Barkla's J phenomenon than to the statistical mechanics of vapour pressure.

The book does contain much interesting material, and the older chapters in particular are very clearly written. However, if one has access to an earlier edition, there is no need to purchase this one. The collection of exercises at the end of the book will continue to be useful to teachers.

G. Wyllie.

THEORY OF FLIGHT

By Richard Von Mises

New York : Dover Publications Inc. Pp. xvi+629. Price $2.85.

A very warm welcome should be accorded to the appearance of Von Mises's classic *Theory of Flight* in the Dover series. The original version of the book which appeared in 1944, written in collaboration first with Prager and later Kuerti, owed something of its origin to Von Mises's earlier and more elementary German text " Fluglehre." As Dr. Hohenemser says in his preface to the Dover edition the *Theory of Flight* is a pre-revolution book—speeds are assumed to be sufficiently low so that compressibility effects are unimportant, the engine is of reciprocating type and propulsion is by airscrew. Only a classic can survive in these circumstances but survive it does and it owes its survival to the penetrating mind Professor Von Mises brought to bear on the many-sided problems of fluid mechanics in which he was interested. As well as being of obvious interest to the historian of the subject it has much to teach the present day student.

L. Howarth.

TRAVAUX PRATIQUES DE PHYSIQUE NUCLEAIRE ET DE RADIOCHIMIE

By M. Duquesne, R. Gregoire, M. Lefort

Paris : Masson & Cie. Pp. 318. Price 39 NF.

This book, which is much more than a miscellany of experiments, deals with the detection of nuclear radiations and the methods used in the study of nuclear structure. It is intended for students of nuclear physics and chemistry and for those who are concerned with practical instruction in this field.

Details of forty typical experiments from the course on nuclear physics and radioactivity at the Faculté des Sciences de Paris are presented clearly and concisely. Although the book has a practical bias, each section is prefaced by a brief review of necessary preliminary knowledge.

Two appendices provide useful surveys of radiological protection, sources of ionizing radiations, tables of units and a selection of suitable problems.

The bibliography makes full use of the English publications, Annual Review of Nuclear Science and Progress in Nuclear Physics.

The layout of the book is good. Clear diagrams, tables and graphs, together with full details of experiments chosen to illustrate established techniques in both physics and chemistry, combine to make it attractive to students. In the absence of a selection of comparable publications in this country, it will be welcomed by organizers of courses in radioisotope techniques and by those who are already engaged in the applications of these techniques in research and industry.

O. C. Gay.

THEORY OF DIFFERENTIAL EQUATIONS (SIX VOLUMES BOUND AS THREE)

By Andrew Russell Forsyth

New York : Dover Publications Inc. Pp. xliii + 1474. Price $15.00 the set.

This great work of Forsyth's, formerly in six volumes, is now reprinted unabridged in three. It remains equally impressive and, I hope, not too forbidding for the real student to browse through. As one handles these volumes one recaptures in some measure the early experience of meeting them for the first time. Here is pure mathematics, so much generality and yet so much detail, so attractive in its argument and yet so overwhelmingly monumental. Must one, how could one, know all this ? To-day one admires again Forsyth's mastery of the subject and marvels that he could have found time to write these as well as his other great contributions to mathematical literature. The task occupied twenty-one

years of the earlier part of his life, and yet in the preface to the last volume, which he wrote in 1906, there is a reminder of the economy of treatment that animates the whole and an awareness of so much that remained to be solved. He writes " I have tried to deal as completely as possible with what seems to me to be essential : and I have omitted what are purely formal extensions ". Again " a perusal of the volume will show that, outside the limits of Cauchy's existence-theorem, knowledge is fragmentary ". And later, " only the simplest extensions are discussed : they could be amplified to any extent : but the result would be merely an accumulation of formal theorems possessing neither individuality nor intrinsic value ".

The re-printing of this mathematical classic raises again the educational problem of how the student of to-day is to get a glimpse of the work and outlook of the outstanding men of even the recent past, and yet be aware of the developments on the present frontiers of the subject. The world of Forsyth seems so far removed from that where the solution of differential equations yields to electronic computers and numerical devices.

J. Topping.

HEAT AND THERMODYNAMICS

By J. K. Roberts and A. R. Miller

Glasgow : Blackie & Son Limited. Pp. xx+619. Price 45s.

Reading the 5th edition of Roberts and Miller's *Heat and Thermodynamics* one is reminded in various ways that the 1st edition came out 32 years ago. Even the appearance of the book, the type-face, and—quite unreasonably—the colour of the paper recall this, as does a reference to work carried out in 1925 in the words: " it has recently been shown that . . ." Certainly there have been revisions and additions—the 1st edition had 441 pages of text, the 4th edition in 1951 had 568 pages, and the new edition has 592 pages, of which about 40 pages are new material. But I feel that in this case at least, Blackie and Son's economical policy of publishing revisions of old-established texts has gone far enough.

There are a number of substantial changes between the 4th and 5th editions, and since they are presumably the publishers' justification for producing the new edition, they should be recorded.

Chapter I, on " Temperature," has been extended to include a fuller discussion of the difference between the international and thermodynamic scales, in the light of the recent decisions of I.U.P.A.P., and chapter XIII presents relevant new material on the determination of the triple point of water. In chapter IV, titled " Equation of state for gases," some fairly extensive rewriting introduces more modern views on the law of corresponding states; a spot-check showed that the table of Contents and the Index have not always kept track of the rewriting.

Additions in later chapters include accounts of two-stage demagnetization (chapter V), of Landau's quantum hydrodynamical theory of liquid helium (chapter XVII), and a discussion of the unattainability of the absolute zero in a quantal system (chapter XIX). Chapter XII is improved by the inclusion of a fuller statement and discussion of the 2nd Law, while new material on the theory of the liquid state appears in chapter XXIII. Among recent experimental work, mention is made of important refinements in the design and technique of the Bunsen ice calorimeter (chapter IX), of measurements of the velocity of sound in free air (chapter VI), and of Bowden's work on the role of friction in skiing (chapter XVI).

Some space has been gained—regrettably, in my view—by the deletion from chapter II of detailed accounts of experiments on the mechanical and electrical equivalents of heat prior to 1920: consequently the work of Rowland, Griffiths, Schuster and Gannon, and Callendar and Barnes, among others, now receives only passing mention.

Elsewhere much-needed rewriting has not been attempted. Thus the material on radiation and Planck's law in chapters XX and XXI has been left practically untouched. After a thermodynamical derivation of Wien's displacement law we are plunged abruptly into a detailed discussion of the experimental consequences of Planck's law. Not until fourteen pages later, at the start of the next chapter, are we told that " thermodynamics alone can carry us no farther than the deduction of Wien's displacement law." There follows a derivation of Planck's law, which requires the assumption that " the only possible energies of a simple harmonic vibration of frequency ν are $(n+\frac{1}{2})h\nu$," an assumption which nowadays comes easily enough ; but confusion is produced by a footnote which has survived irrelevantly from the earlier editions in which the energies were assumed to be $nh\nu$. This footnote now belongs on the first page of the next chapter, where the older assumption about the energies of the quantized oscillator reappears.

As an undergraduate I found Roberts' book dull, though useful about experiments, and about the Gibbs function. The latest edition seems to me duller, and less useful about the experiments a student might want to look up. The authors' interest in precise measurement is apparently held to justify the omission of accounts of many qualitative and older experiments, but the very detailed descriptions of the best modern apparatus and measurements break up, rather than illuminate, the general argument. Such descriptions hardly belong in an undergraduate text unless they form part of an account of the history of the experiment, or are accompanied by a commentary which explains to the student the reason for the refinements of technique ; this is completely lacking. The result is a book professedly " written from the experimental point of view " and replete with details of apparatus and measurements, which yet gives the student little idea either of the interplay of experiment and theory or of the development of experimental technique.

Careful revision, planned to involve the minimum of resetting, has enabled the publishers to keep the price of this large book down to 45s., but the defects of age which characterize it call for more drastic treatment. The recent books by Zemansky and by Sears are a good deal more expensive, but they will be more widely recommended and used.

R. M. Sillitto.

Forthcoming Institute and Society Meetings

Date	*Place*	*Speaker*	*Title and other details*	*Time*	*Branch or Group*
Oct. 24	**Manchester** The University	Professor W. H. G. Armytage *(University of Sheffield)*	**The endless frontier**	7.00 p.m.	Manchester and District
Oct. 26	**London** Headquarters		Half-day meeting on **New techniques in stress analysis** Registration for this meeting is necessary.	2.30 p.m.	Stress Analysis
Oct. 26	**Birmingham** College of Advanced Technology		Annual General Meeting, followed by a lecture. (details to be announced later)	6.30 p.m.	Midland
Oct. 28	**London** Headquarters		Branch **At home** Registration for this event is necessary.	7.30 p.m.	London and Home Counties
Nov. 2	**Glasgow** The University	Professor D. J. E. Ingram, F.Inst.P. *(University College of North Staffordshire, Keele)*	**Electron spin resonance**	7.15 p.m.	Scottish
Nov. 2	**Manchester** College of Science and Technology	Dr. G. A. Taylor, F.Inst.P. *(Manchester College of Science and Technology)*	**Recent developments in optical transform techniques**	7.00 p.m.	X-Ray Analysis
Nov. 2	**Newcastle-upon-Tyne** King's College	Dr. J. W. Glen *(University of Birmingham)*	**The physics of glaciers**	6.15 p.m.	North-Eastern
Nov. 3	**St. Andrews** The University	Professor D. J. E. Ingram, F.Inst.P. *(University College of North Staffordshire, Keele)*	**Electron spin resonance**	5.00 p.m.	Scottish
Nov. 4	**Aberdeen** The University	Professor D. J. E. Ingram, F.Inst.P. *(University College of North Staffordshire, Keele)*	**Electron spin resonance**	7.30 p.m.	Scottish
Nov. 4	**Exeter** The University	Professor C. W. Allen, *(University College, London)*	**Astrophysical uses of spectroscopy**	5.30 p.m.	South Western
Nov. 9	**Leeds** The University	Dr. B. J. Mason *(Imperial College of Science and Technology, London)*	**The generation of electricity in thunderstorms**	5.00 p.m.	Yorkshire
Nov. 9	**London** Imperial College	Mr. L. B. Happé Mr. J. Vickers	**Visual assessment of colour ciné films** **Assessment of photographic colour prints**	3.00 p.m.	Colour
Nov. 10	**Liverpool** The University	Professor W. V. Mayneord, C.B.E., F.Inst.P. *(Institute of Cancer Research, London)*	**The natural and artificial radioactivity among which we live**	7.00 p.m.	Liverpool and North Wales
Nov. 11	**London** Headquarters	Mr. F. R. Bareham, Dr. J. Blitz, Dr. R. W. G. Hazlett, F.Inst.P., Mr. V. J. Upton	A colloquium on **The principles and practice of eddy current testing**	6.00 p.m.	Non-Destructive Testing
Nov. 11	**London** Royal Microscopical Society		One-day meeting including the Group Annual General Meeting followed by papers on **Some physical aspects of the electron microscope** Registration for this meeting is necessary.		Electron Microscopy

The Journals

PRINCIPAL CONTENTS OF THE OCTOBER, 1960, ISSUES

British Journal of Applied Physics: Volume 11, No. 10

CONFERENCE REPORT

Summarized proceedings of a symposium on the generation of temperatures below 1°K—London, December, 1959. By D. H. Parkinson.

A one-day symposium on the methods of generating temperatures below 1°K was held by the Low-Temperature group of The Physical Society on December 11, 1959. Six papers of a review nature were read and discussed. Attention focused primarily on the techniques of adiabatic demagnetization and on the use of ^3He ; nevertheless some of the more difficult techniques were reviewed with the more recently discovered properties of ^3He.

Pre-breakdown conduction in continuously-pumped vacuum systems. By W. K. Mansfield, A.Inst.P.

Measurements have been made under impulse conditions of the coefficients A′, the number of H^+ ions emitted per 250 keV H^- ion, and B′, the number of H^- ions emitted per 250 keV H^+ ion, for metal surfaces covered with the contaminating layers likely to be formed in continuously-pumped high-voltage apparatus. The values obtained for A′ were 1·0, 1·1 and 0·54, and for B′ 0·43, 0·24 and 0·44 for copper, aluminium and steel targets respectively. The product of these coefficients is such as to make very probable the hypothesis that pulse discharge conduction in these systems is due to the regenerative exchange of positive and negative ions of hydrogen. The transient nature of this form of conduction is thought to be due to the charging up of the insulating contaminant.

Use of an electrical analogue for the solution of a variety of torsion problems. By Professor S. C. Redshaw.

A brief review of Saint-Venant torsion theory is given and the advantages and disadvantages of the various forms in which the equations can be expressed are discussed in relation to electrical analogue computation. It is shown how, by the use of a simple passive resistance network, solutions can easily be obtained both for simply connected regions as well as for the analytically difficult problem of multiply connected regions. Examples of the application of the electrical-analogue method to the problems of plastic torsion, the torsion of compound bars, thick hollow sections and thin-walled sections filled with a dissimilar material, are given.

Importance of insulating inclusions in arc initiation. By R. Hancox.

The initiation of arcs on a metal surface in contact with a plasma (ion density about 10^{14} ion/cm^3) has been studied with metal specimens known to contain microscopic alumina inclusions. The specimens were biased negatively with respect to the plasma, and for voltages above 300 V the time lag before arcing occurred was inversely proportional to the positive ion current drawn by the specimen from the plasma, but independent of voltage. At lower voltages the time lag increased rapidly with decreasing voltage. Arcing was also independent of the nature of the ions and the pressure of neutral gas in the plasma. These results are consistent with the initiation of the arcs by dielectric charging and breakdown of the inclusions.

Measurement of convective heat transfer by means of the Reynolds' analogy. By R. A. Granville, A.Inst.P., and Genefer Boxall.

Preston's method for measuring skin friction in pipes has been extended to include non-uniform flow, with and without pressure gradients, over flat surfaces. By means of a modified form of the Reynolds' analogy, the local convective heat transfer coefficient can be related to the skin friction, and it is proposed that the method be used in aerodynamic models of furnaces and in heat transfer plant of simple geometry. More investigations are required of the effects of fluid turbulence, surface roughness and surface curvature on convective heat transfer and skin friction.

Determination of preferred orientation in polycrystalline metal foils using a sputtering technique. By R. S. Nelson.

The preferred crystal orientation of metal foils has been qualitatively analysed by observing the pattern produced when atoms sputtered from the surface in a gas discharge are collected on a plate.

Journal of Scientific Instruments: Volume 37, No. 10

Magnetic probes of high frequency response. By S. E. Segre and J. E. Allen.

Probes for the measurement of the magnetic field distribution in fast pulsed discharges have been constructed. Their frequency response has been measured and agrees well with that calculated from an equivalent circuit. The probes described have an attenuation flat (to within 1%) up to 20 Mc/s.
A criterion is given which states the optimum value for the impedance of the recording circuit.

Transistorized frequency stabilisation for reflex klystrons used in magnetic resonance. By P. Jung.

The description of a fully transistorized frequency stabilizer for reflex klystrons is given. This is suitable for magnetic-resonance experiments and other microwave applications, where frequency stability is essential. In a typical case (klystron, type 2K25, cavity Q = 3000) the effect of ripple and drift of the power supply is reduced by a factor of 1000.

Cyclic shearing interferometer. By P. Hariharan, A.Inst.P., and D. Sen.

A wavefront shearing interferometer is described which can be conveniently used for routine tests of optical systems with relative apertures of f/6 or less. The necessity of equalizing the two optical paths has been eliminated in this instrument, making it extremely easy to adjust and handle. At the same time, the shear can be continuously varied, so that zonal errors can be easily identified.

Automatic range-changing of a linear ratemeter. By S. Lovett.

A circuit is described which automatically changes the range of a linear ratemeter as the count rate from a flow Geiger counter increases or decreases. The counter voltage is switched off when the count rate exceeds the maximum that the counter is designed to accept and is switched on at intervals to sample the count rate and remains on when the rate has diminished to an acceptable level.

Production of a pulsed magnetic field using an electrolytic capacitor bank. By D. G. Bate and R. F. Saxe.

An economical system for obtaining magnetic fields of the order of 10^4 G lasting for times of the order of milliseconds is described. A switch is operated by a falling mercury column and performs two switching operations separated by an adjustable, repeatable delay of a few milliseconds. Currents of the order of 10^4 A flow through the switch during operation. The source of stored energy is a capacitor bank of large capacitance and low voltage, and this is discharged through a solenoid by means of the switch.

An X-ray fluorescence method for determination of the transition-metal content in very small specimens of alloys. By P. J. Brown.

A method is described for the quantitative determination of the transition metal content in very small quantities of alloys containing transition metals of the first long period. The method depends upon measurement of the intensity of the fluorescent X-rays emitted by the specimen, and the results are evaluated by comparison with a series of standards. An accuracy of better than 1% can be achieved in specimens containing as little as 0·2 mg of the transition metals.

Transformer bridges for use with resistance strain gauges and similar transducers. By L. N. Clarke.

A method of balancing a.c. bridges having transformer ratio arms is described which is particularly suitable for use with resistance transducers such as electrical-resistance strain gauges. The long-time stability and accuracy of reading can be readily made better than required for most static testing by the use of an auxiliary transformer. The bridge can be combined with a commercial potentiometric recorder to form a multi-channel self-balancing a.c. bridge which can provide different ranges on successive channels. The balancing system lends itself to the control of testing machines, especially for the production of a given time-pattern of load or strain. The use of other types of transducers is considered.

Production of millimicrosecond current pulses using a pressurized spark gap. By J. H. Adlam and L. S. Holmes.

A pressurized spark gap has been designed to discharge a number of coaxial cables in parallel, thus producing a current pulse of 10^4 A with a rise time of 4·5 mμs. It is intended to use a number of these spark gaps in parallel, and to test the feasibility of doing this, measurements have been made of the statistical variation of the time lag for breakdown after triggering.

An electronic apparatus for the study of X-rays with proportional counter. By N. Patla.

The design and construction of an electronic pulse recording system for use with a proportional counter suitable for X-ray studies is described. The performance of the high gain amplifier and pulse amplitude analyser for X-ray wavelength discrimination is discussed in detail.

Papers accepted for publication in *Proceedings of The Physical Society*

The Separation of Symmetrical and Asymmetrical Wave-front Aberrations in the Twyman Interferometer. By P. Hariharan and D. Sen.

By reflecting the two wave-fronts emerging from a Twyman interferometer back through the interferometer once again, it is possible to obtain two separate interferograms showing, respectively, the symmetrical and asymmetrical parts of the wave-aberration of an optical system. These can then be analysed to obtain the various aberration coefficients of the system in a very simple manner.

Measurement of Townsend's Ionization Coefficients and Attachment Coefficients in Oxygen. By A. N. Prasad and J. D. Craggs.

Prebreakdown currents and breakdown potentials have been measured in oxygen over a pressure range of 60-600 mm Hg and an E/p range of 35 to 50 V/cm/mm Hg. From the semi-logarithmic plots of current against electrode separation, the Townsend ionization coefficient α/p, and attachment coefficient η/p and a generalized secondary coefficient γ (where present) have been evaluated employing the modified Townsend current growth equation. From the values of α/p and η/p so obtained and from the earlier measurements, the mean cross section for ionization and attachment have been evaluated and by comparison with those obtained from low pressure (single collision) experiments, the electron attachment in O_2 under high pressure swarm conditions has been interpreted in terms of the dissociative attachment process. Lastly from the measured values of α/p, η/p and γ, values of the breakdown gap d_s have been evaluated for the E/p range 40-50, employing the modified Townsend breakdown criterion and by comparison with the measured values, the uniform field breakdown in O_2 at threshold has been interpreted in terms of the Townsend build up processes up to a pd $\simeq$ 250 mm Hg cm.

Integrable Many Body Wave Functions for a System of Bose Particles. By S. F. Edwards and M. A. Naqvi.

It is shown that, by means of a parametric representation, a variational calculation for a system of Bose particles can be carried through using explicit trial wave functions which describe a state with a fixed number of particles and include pair correlations. For the ground state the results of previous work are obtained as the first term in a steepest descent calculation. An effective Schrödinger equation is obtained for the relative motion of two particles. The application of the method to excited states is discussed ; in particular for the case of a vortex line in the system it is shown that the method leads to an analysis which is very similar to that for the ground state and can be carried through in the same way.

Redetermination of the Panofsky Ratio for Negative Pions Stopped in Hydrogen. By D. P. Jones, P. G. Murphy, P. L. O'Neill and J. R. Wormald.

A lead-glass Cerenkov counter has been used as a gamma-ray spectrometer to redetermine the Panofsky ratio for negative pions stopped in hydrogen. The ratio was found to be $1{\cdot}56 \pm 0{\cdot}05$.

RESEARCH NOTES AND LETTERS TO THE EDITOR

The 0^+, T = 1 level in ^{18}F. By D. Eccleshall and M. J. L. Yates. (Research Note.)

Electric conduction in antiferromagnetics. By G. L. Sewell. (Research Note.)

Impurity photoconductivity in n-type InSb. By E. H. Putley. (Letter to the Editor.)

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